June 24, 2019

<u>Ex Parte</u>

Marlene H. Dortch, Secretary
Federal Communications Commission
445 12th Street SW
Washington, DC 20554

Re: *Unlicensed Use of the 6 GHz Band*, ET Docket No. 18-295; *Expanding Flexible Use in Mid-Band Spectrum between 3.7 and 24 GHz*, GN Docket No. 17-183

Dear Ms. Dortch:

On June 20, 2019, representatives from Apple Inc., Broadcom Inc., Cisco Systems, Inc., Facebook, Inc., Google LLC, Hewlett Packard Enterprise, Intel Corporation, Marvell Semiconductor, Inc., and Qualcomm Incorporated met with representatives of the Office of Engineering and Technology. A complete list of participants is attached to this letter.

During the meeting, we discussed the attached presentation addressing the technical analysis of RLAN-FS interactions relevant to proposals in the Commission's Notice of Proposed Rulemaking in the above-referenced dockets to open the 6 GHz band for unlicensed technologies. We discussed the analysis in the record showing that RLAN operations will protect FS links, including the detailed engineering study prepared by RKF Engineering.

Specifically, we explained that the RKF analysis included simulated RLAN-to-FS interactions including both free-space propagation conditions and 0 dB of building entry loss (and in very rare cases *less* than 0 dB). For each of the approximately 1 billion RLAN devices 'dropped' in each run of the RKF Monte Carlo simulation, the simulation algorithm selected values at random across the entire range of each of these distributions, in proportion to their respective probabilities. Thus, for example, among RLAN devices 5 kilometers away from a given FS receiver, the selected propagation values resulted in approximately 25% exhibiting free-space path loss, and approximately 45% exhibiting 130 dB of propagation loss or less. Similarly, for building entry loss, values for indoor RLAN devices were selected at random such that, for example, roughly 50% exhibited building loss of 19 dB or less, and 10% exhibited 6.5 dB or less.

We additionally discussed that RKF was even more conservative than this, as it did *not* account for the fact that real-world RLAN devices typically have multiple antennas which transmit at peak EIRP in only a single direction, with substantially lower emissions in other directions, thus further limiting the total energy an FS could receive from an RLAN device. We presented results from empirical measurements of existing RLAN devices to confirm these conclusions. The fact that RKF did not take this factor into account, instead assuming that devices could transmit peak system power in the direction of an FS, makes its analysis even more conservative.

Finally, we discussed RKF's analysis of FS link margin, which was performed as a separate analysis from the I/N analysis. FS licensees have asserted that FS receivers use 25 to 40 dB of margin to operate reliably during fade conditions. Our analysis, based on link operating parameters found in ULS, shows the vast majority of FS receivers have design margin well in excess of that range. Broadcom has separately confirmed this analysis.[1] In addition, RKF separately analyzed the small number of links that resulted in -6 dB I/N exceedances and found that, due to available link margin, the availability design target of those links would not be reduced (e.g., a link designed at five 9's would continue to operate at five 9's because of the significant margins of these links). Thus, although the RKF report concluded that less than 0.2% of simulated RLAN-FS interactions would result in -6 dB I/N exceedance, even this small percentage does not take into account FS link margin and other important factors that will significantly reduce the risk of harmful interference even further. As we noted, this result also did not address a number of other important factors, most significantly the existence of an AFC system to prevent interference from standard-power devices.

Pursuant to the FCC's rules, I have filed a copy of this notice electronically in the above referenced dockets. If you require any additional information, please contact the undersigned.

Sincerely,

Paul Margie
Counsel to Apple Inc., Broadcom Inc., Cisco Systems, Inc., Facebook, Inc., and Hewlett Packard Enterprise

Enclosure

Cc: Meeting participants

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[1] *See* Letter from Paul Caritj, Counsel for Broadcom Inc., to Marlene Dortch, Secretary, FCC, ET Docket No. 18-295 (filed Mar. 29, 2019).

MEETING ATTENDEES

Julius Knapp (OET)
Bahman Badipour (OET)
Navid Golshahi (OET)
Michael Ha (OET)
Sayed Hasan (OET)
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Hugh Van Tuyl (OET)
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Chris Szymanski, Broadcom Inc.
Vinko Erceg, Broadcom Inc.*
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Chuck Lukaszewski, Hewlett Packard Enterprise*
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Hassan Yaghoobi, Intel Corporation*
Yi-Ling Chao, Marvell Semiconductor, Inc.*
John Kuzin, Qualcomm Incorporated
Tevfik Yucek, Qualcomm Incorporated*
Paul Margie, Harris, Wiltshire & Grannis LLP
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* Participated telephonically.

6 USC Presentation to the Office of Engineering and Technology

RLAN-FS Interactions

June 20, 2019

Overview

- The FCC can permit LPI and VLP RLAN operations that protect FS links.
  - The vast majority of FS receivers are located far away from areas where RLANs operate—either well outside of metro areas, or situated well above surrounding RLAN operations.
  - There is little chance of RLANs being located near the receiver, anywhere near its main beam and outside of the clutter field.
- Even if an RLAN is near the receiver or near the main beam, a variety of other factors will prevent harmful interference, depending on the device class.
  - The RLAN device would need to be operating in the 6 GHz band, and co-channel with the FS Receiver.
  - Peak RLAN EIRP will typically not be directed towards the FS receiver.
  - Propagation, clutter, building attenuation, antenna boresight mismatch, body loss (for handheld devices) and polarization mismatch all lead to RLAN signal attenuation and enormous reductions in interference potential.
- Even in rare cases where an FS receiver receives atypically high levels of RLAN energy, very high FS C/I levels prevent this energy from affecting FS links.
  - We have suggested a -6 dB I/N threshold for analysis, but most FS receivers can tolerate significantly higher levels before harmful interference occurs.
  - Thus, even if an LPI or VLP RLAN were to exceed this proposed level, it would only affect an FS link in the extremely unlikely case that this exceedance happened to a link without sufficient margin.

Record Recap

- The record includes detailed analyses of the factors that will prevent harmful interference to FS.
  - The RKF study in 2018 included a detailed analysis of FS/RLAN interactions by simulating a wide range of possible RLAN deployment patterns. This analysis included standard-power outdoor devices (which AFC will mitigate) and did not include important sources of loss which would reduce the risk further.
  - RLAN companies deepened this analysis in our NPRM comments, showing the relationship between distance to an FS receiver and exceedance, and showing that exceedance conditions are very rare.
  - In addition, Broadcom filed a detailed analysis of recently registered FS links that shows that, even in the rare case where RLAN energy at an FS receiver exceeds -6 dB I/N, there is no realistic chance of harmful interference.

Monte Carlo Analysis

- Monte Carlo analysis involves mapping all known fixed links, randomly dropping RLAN devices in proportion to the population and then calculating the interference potential for each RLAN into each FS receiver.
- This is done repeatedly to ensure that unlikely situations are captured, leading to millions of RLAN to FS interference morphologies.

$$\mathbf{Interference} = \mathbf{GRX} - \mathbf{OffAxis} - \mathbf{Pathloss} - \mathbf{BEL} + \mathbf{EIRP}$$
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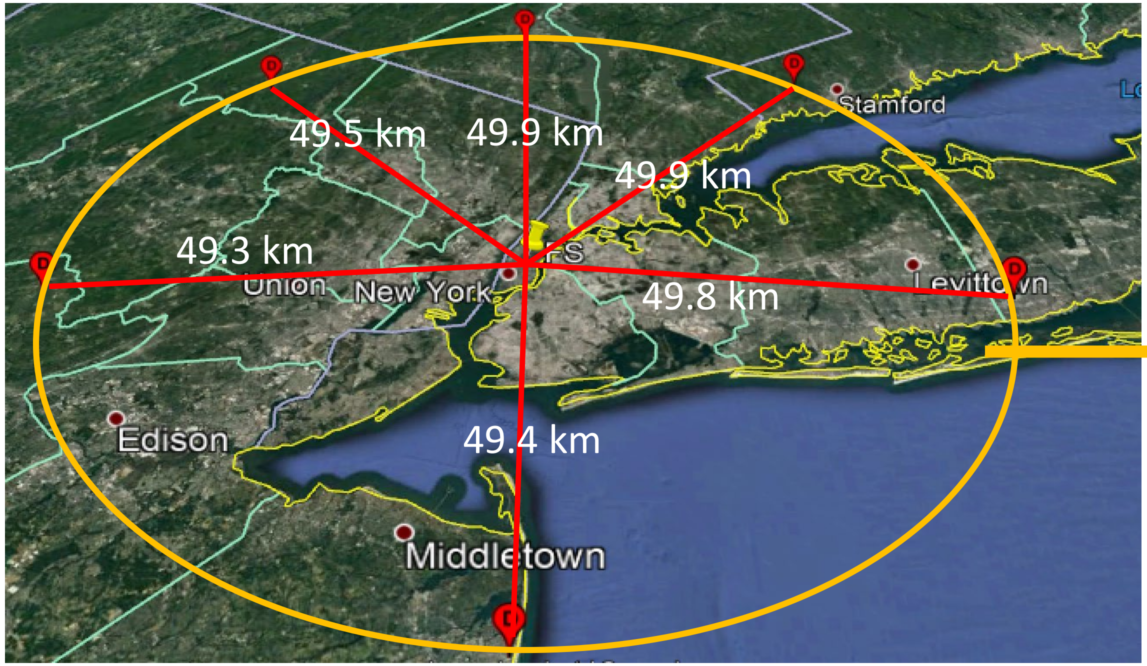
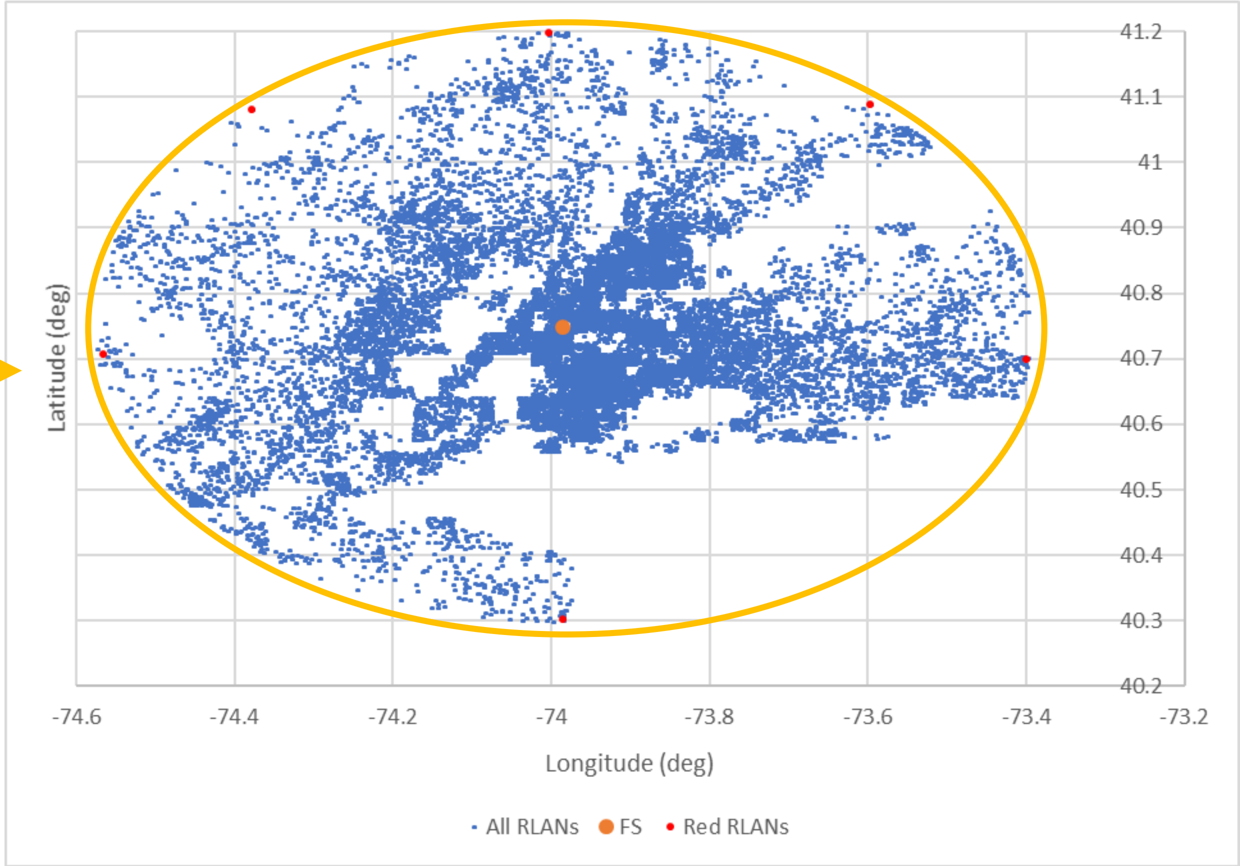
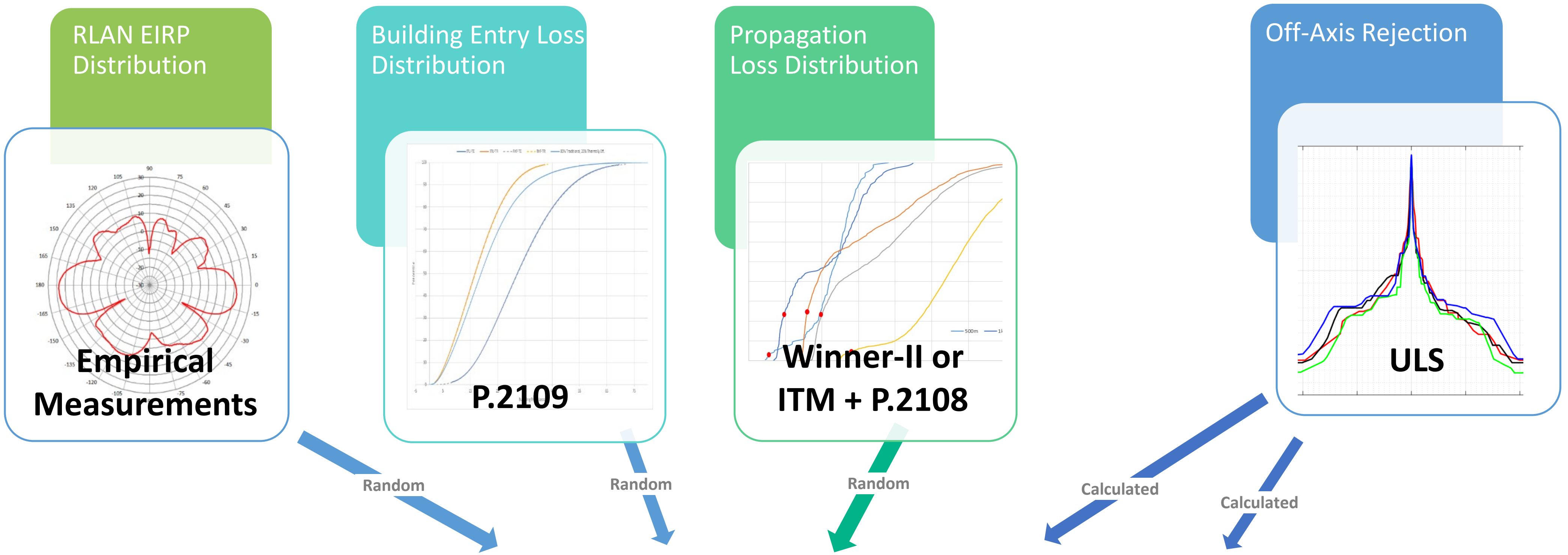
What Is a “Random Drop” of RLAN Devices?

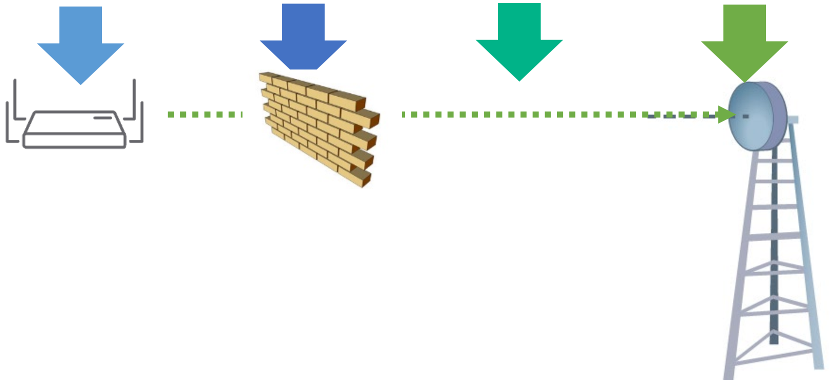




Factors in an RLAN to FS Interference Model

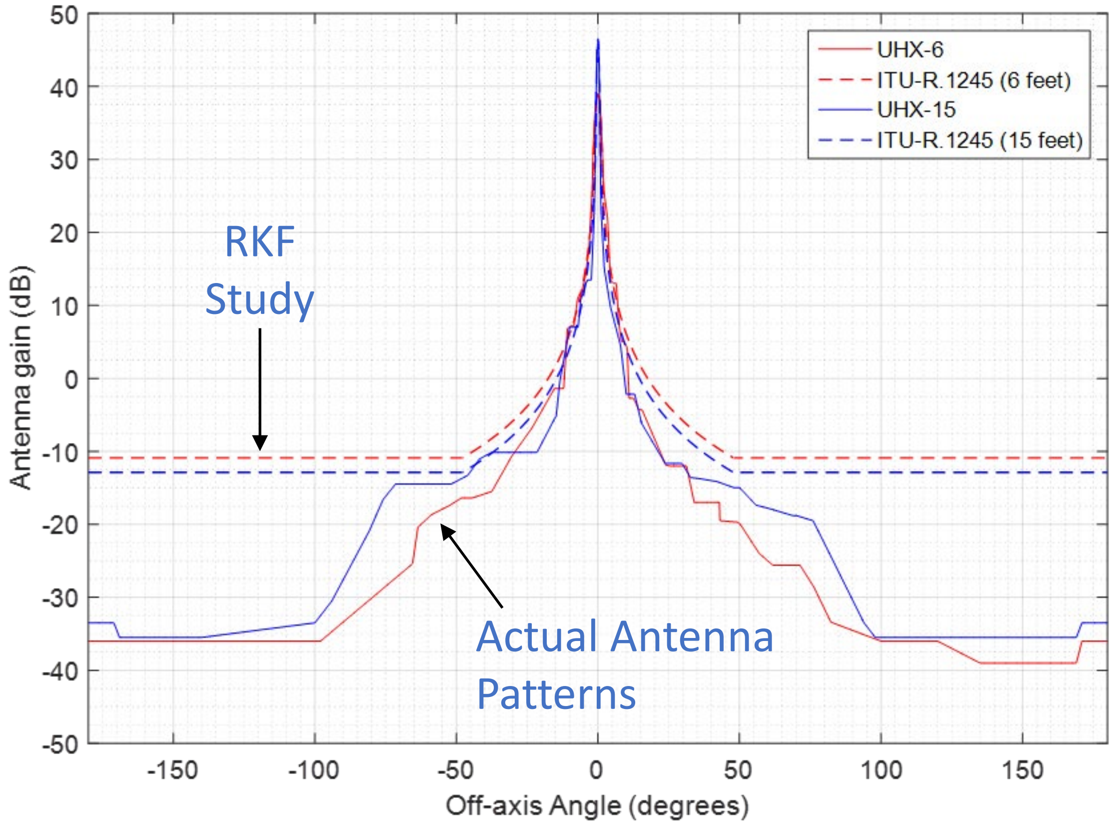


$$\boldsymbol{Interference = EIRP\ - BEL - Pathloss\ +\ GRX\ - OffAxis}$$



Factor 1: Off-Axis Rejection and RLAN-FS Geometry Reduces Potential Interactions

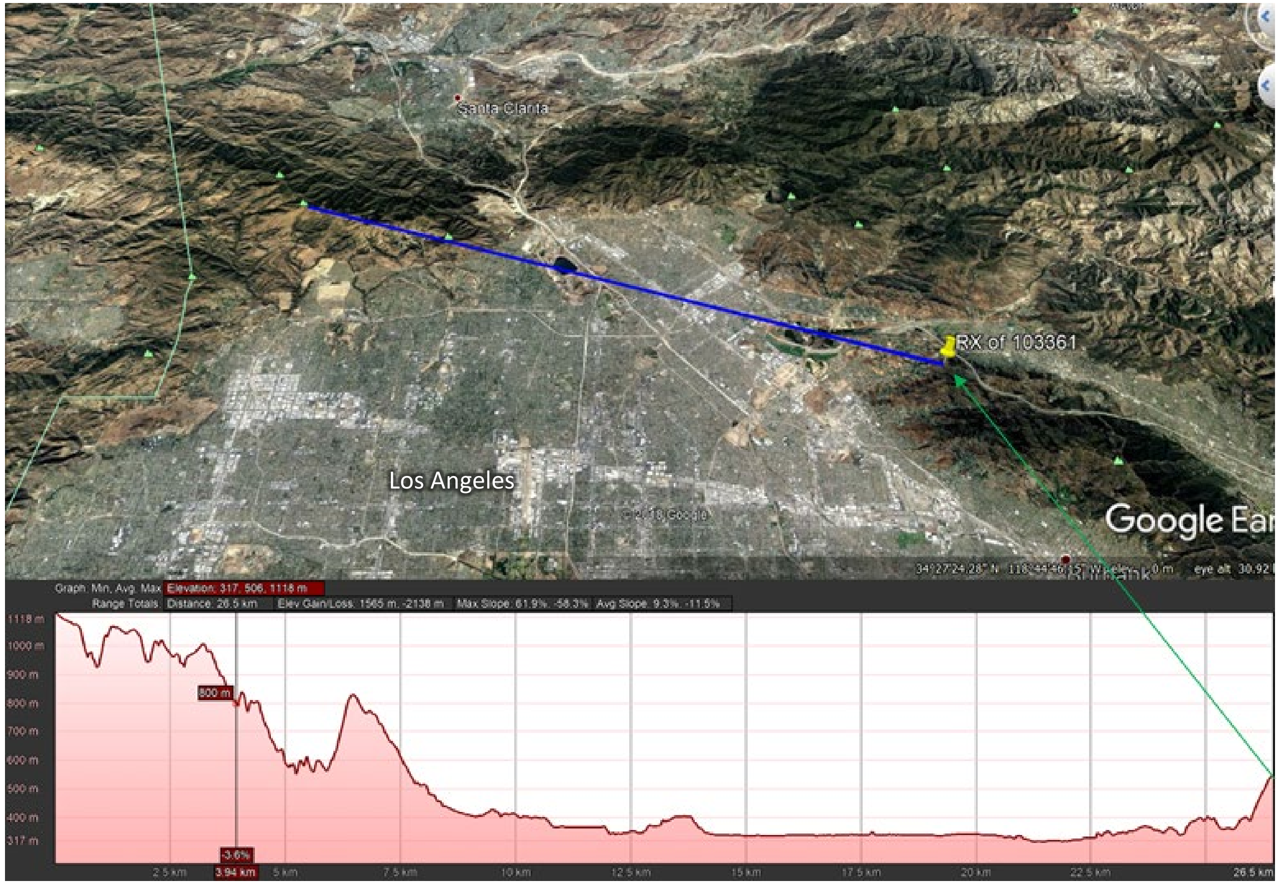
- FS Antennas are highly directional and the antenna gain is attenuated outside of the main beam.
  - Larger antennas typically have higher gain (e.g., 15 ft antenna will typically have 48 dBi) and more rapid attenuation outside of the main beam.
  - Although smaller antennas exhibit slower roll-off as you go off axis, they also typically have lower overall gain (e.g., 6 ft antenna will typically have 39 dBi).



Antenna gain for two different antenna sizes

Factor 1: Off-Axis Rejection and RLAN-FS Geometry Reduces Potential Interactions

- Point-to-point FS antennas are typically installed in locations high above surrounding terrain.
- There is a better chance of being in the main beam as an RLAN device is located farther from the FS receiver. But the chance of having a obstruction in between or the RLAN device being in the clutter is also higher. The propagation loss is also higher.

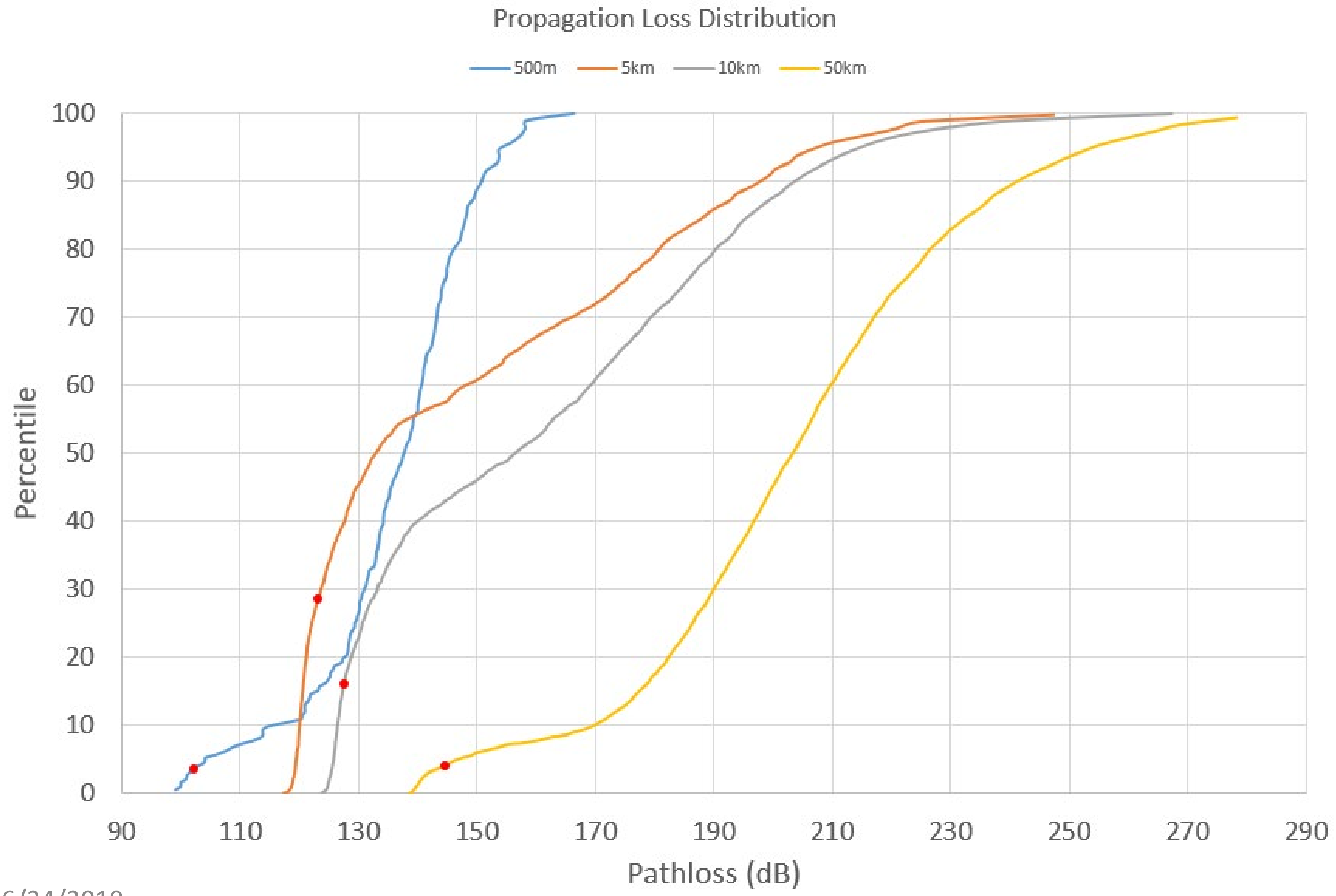


Sample terrain profile for a typical FS link — Callsign WNEU351

Factor 2: Propagation Loss Reduces Energy Reaching FS Receivers

- The distribution of propagation loss values simulated by RKF vary depending on distance, statistical fading/clutter, and line-of-sight probability.
  - RLAN devices farther away will tend to exhibit greater attenuation due to both longer propagation distance and higher probability of obstruction.
  - Rural areas will yield a higher probability of free-space conditions.
- RKF used distributions reflecting a combination of WINNER II Line of Sight, WINNER II NLOS, and ITM/SRTM+clutter, determined by the land category (urban, suburban, rural) for each random RLAN.
- The RKF study model includes *all* of these outcomes, including free-space, consistent with the NPRM (para 49).

Factor 2: Propagation Loss Reduces Energy Reaching FS Receivers



For any given RLAN-FS distance, a full distribution of path loss values occurred. No "averages" were used.

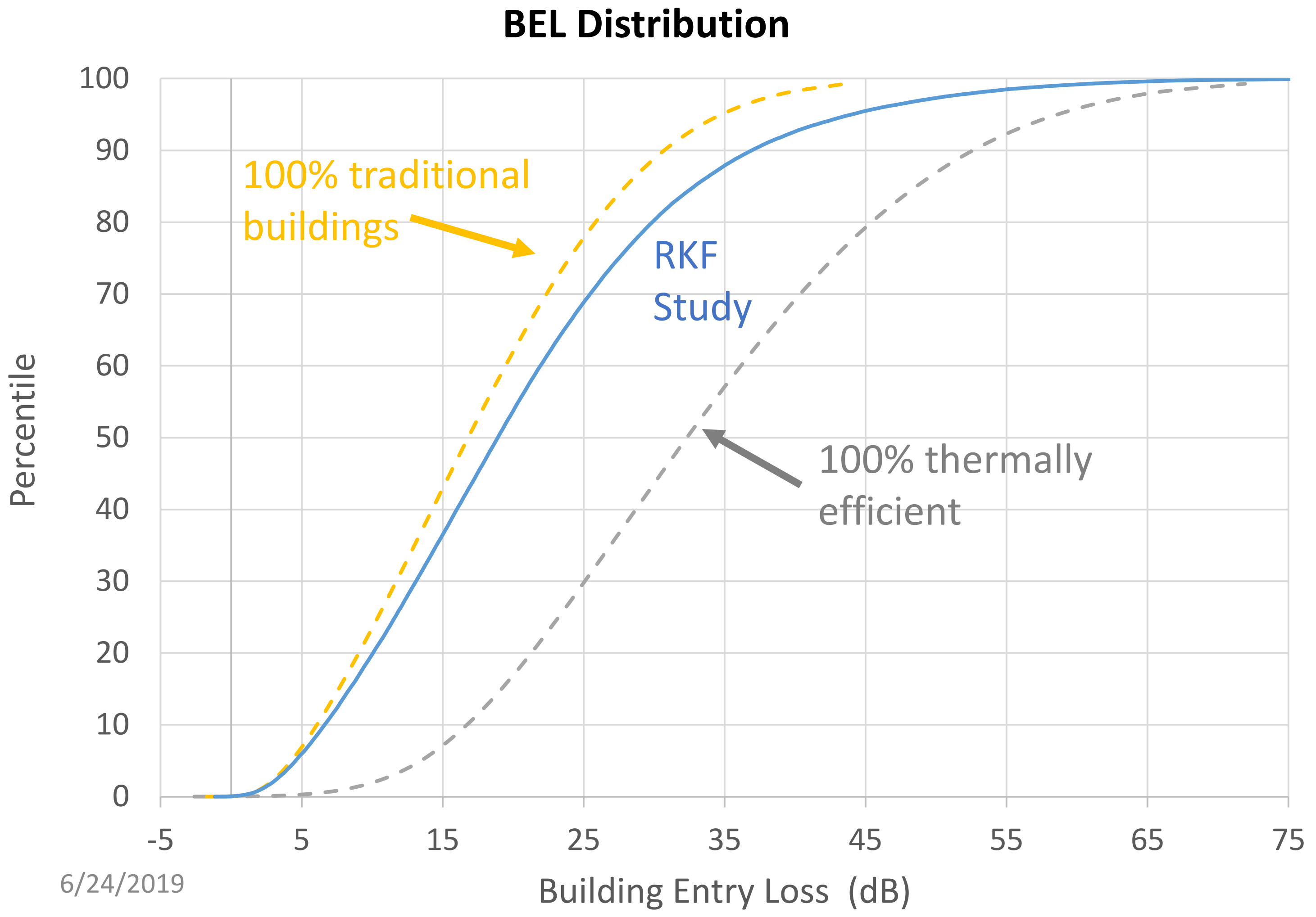
To illustrate this, this plot depicts path loss distributions for four different RLAN-to-FS distance bins. As expected, the distributions "widen" as the distance increases.

The red dot indicates when the path loss for the propagation model is equivalent to free space loss at 6500 MHz.

Factor 3: Building Entry Loss Further Attenuates RLAN Signals

- ITU provides the distribution shown in the next slide for traditional and thermally efficient buildings.
- As we explained (and as the Qualcomm measurement data appended to our reply comments indicates) this distribution may significantly underestimate BEL for high-rise buildings in the U.S. due to modern energy efficiency requirements.
- RKF's analysis conservatively assumed that 80% of RLANs would be operating inside traditional (non-thermally efficient) buildings. BEL is also likely higher than our assumption because of AP placement in room centers to maximize coverage.
    - Note that this includes rare cases with zero (and, extremely rare cases with *less than zero*) BEL when calculated using ITU-R P.2109.

Factor 3: Building Entry Loss Further Attenuates RLAN Signals



RKF used the full range of potential BEL values provided by the ITU model.

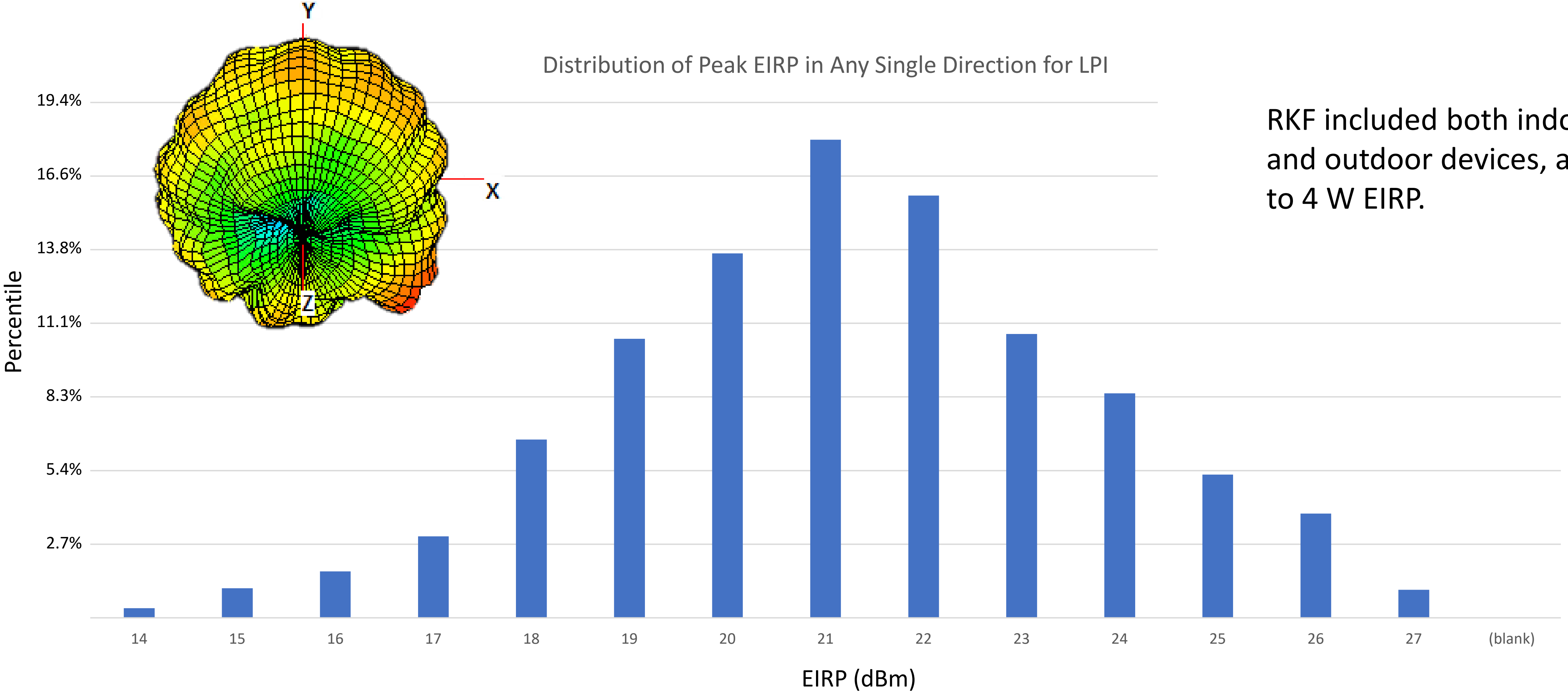
The RKF study used a small proportion of thermally efficient buildings, resulting in a conservative distribution.

This includes a realistic number of small BEL values, including a very small number of cases where BEL <= 0 dB.

Factor 4: Radiated Power Is Rarely at Its Maximum

- RKF considered radiated energy for *all* types of RLAN devices, accounting for real RLAN antenna e-plane patterns.
- Due to the physical design of RLAN AP antennas and the significant height difference relative to FS receivers, RLAN devices will not typically radiate towards an FS receiver at its full radiated power.
- RLAN antennas typically only emit near their maximum EIRP at specific elevations and azimuths.
- Multiple-antenna RLAN APs typically do not point antennas in the same direction in order to maximize coverage. However, peak EIRP is measured as the combined power of all antennas, limiting the power in each direction.

Factor 4: Radiated Power Is Rarely at Its Maximum



RKF included both indoor and outdoor devices, at up to 4 W EIRP.

The Risk of Interference Is Even Lower than RKF Predicted

- The RKF analysis did not include:
  - Polarization mismatch, which would reduce interference by an average of another 3 dB.
  - Feeder loss , which would reduce interference by an average of another 2 dB.
  - Near field rejection , which would significantly reduce interference from RLAN devices near the FS receiver (i.e., within a few hundred meters, depending on antenna size).
  - Consideration of an AFC system, which would have eliminated any potential interference from standard-power devices and outdoor devices.

FS Link Margin Provides Further Protection Against Harmful Interference

- Even the rare case of an RLAN device causing greater than -6 dB I/N will not cause harmful interference in the real world.
- ULS link data shows that virtually all links have far more margin available than what is needed to operate during deep fade.
- We analyzed each link in ULS individually to determine the margin actually available given its antenna, transmit power, modulation, path length, etc.
  - According to FWCC, the typical link requires 25-40 dB of link margin to operate during deep fade conditions.
  - Virtually all links have far more margin available than necessary to operate during deep fade.
- 30% of links in ULS also have diversity antennas, which we have not accounted for, but would further reduce the risk of deep fade impairing a link. These tend to be the links with the greatest reliability requirements.

FS Link Analysis

Link Margin Calculation

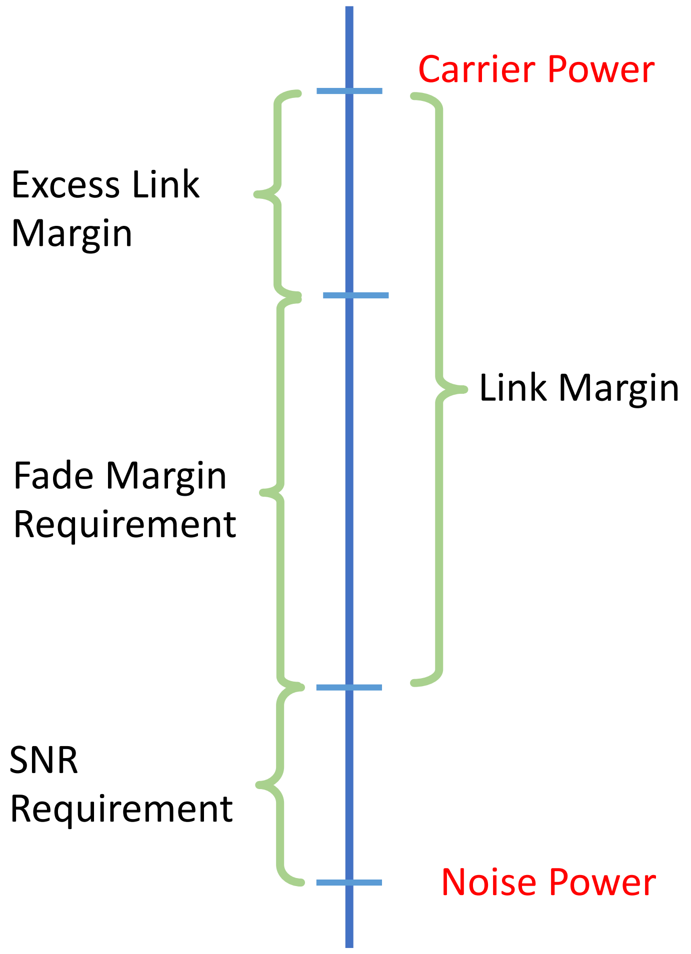
- Calculate/estimate SNR requirements for modulation with highest transmit power in ULS.
- Calculate the Link Margin.

$$\textit{Link Margin} = \textit{FS EIRP} - PL + Gr - NF - S/Nreq - N$$

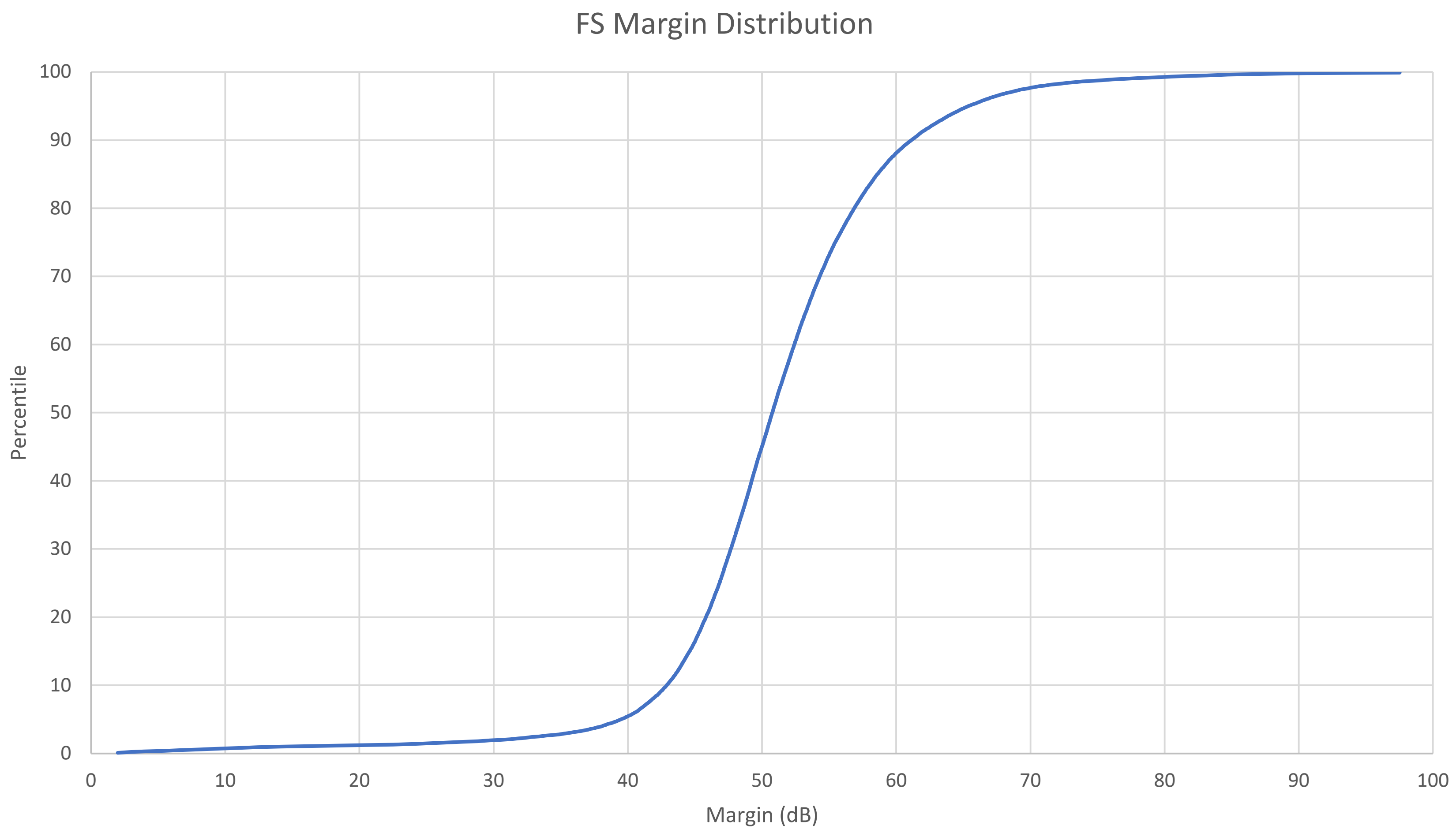
- EIRP = Effective isotropic radiated power (dBW, used highest listed Tx EIRP when links listed multiple powers)
- PL = Free Space Path loss (dB)
- Gr = FS Receive Antenna gain (dBi)
- NF (Noise Figure) = 5 dB
- S/Nreq = Required signal-to-noise ratio (dB)
- N is the thermal noise (dBW, function of the operating channel bandwidth)

Excess Link Margin

- RLAN interfering with un-faded FS signal: FS receiver will be unaffected unless RLAN interference exceeds the *entire* Link Margin.
- RLAN interfering with fully faded FS signal: FS receiver will be unaffected unless RLAN interference exceeds the excess Link Margin.



Virtually All Links Have Over 25 dB in Margin and Approximately 95% Have Over 40 dB for Listed Modulation



Link Margin – Conclusion

- For an FS link to be affected, a series of unlikely events must occur:
  1. An RLAN device must be:
     1. In the 6 GHz band, on the same channels as the FS receiver;
     2. In or near the main beam;
     3. Outside the clutter field;
     4. Oriented so that peak or near-peak RLAN antenna gain is directed towards the FS receiver;
     5. And, for indoor devices, in a non-thermally efficient, low BEL building.
  2. In addition the FS receiver must:
     1. Be experiencing sufficient fade to consume all or nearly all of the FS link's fade margin;
     2. And have so little remaining link margin, that slight degradation in the noise floor (1 dB at -6 dB I/N) can noticeably affect performance.
- All of these improbable situations are very unlikely to occur simultaneously, *even when multiplying this small probability across every FS receiver in the United States*.

Questions?